HE 3.3-8

LATERAL DISTRIBUTION OF HIGH ENERGY HADRONS AND GAMMA RAY IN AIR SHOWER CORES OBSERVED WITH EMULSION CHAMBERS

Matano,T. and Machida,M.
Department of Physics, Saitama University, 338 Urawa, Japan
Kawasumi,N., Tsushima,I., Honda,K. and Hashimoto,K.
Department of Physics, Yamanashi University, 400 Kofu, Japan
Navia,C., Martinic,N. and Aguirre,C.
Instituto de Investigaciones Fisicas
Universidad Mayor de San Andres, La Paz, Bolivia

1. Introduction

We have observed a high energy event of a bundle of electrons, γ rays and hadronic γ rays in an air shower core. This bundle were detected with an emulsion chamber with thickness of 15 cm lead installed in the central part of SYS air shower array at Mt. Chacaltaya. The size of air shower accompanying the bundle is 1.5×10^7 and the age parameter is determined 0.17 from the steepness of the lateral structure. This air shower is estimated to be initiated with a proton with energy around 10^{17} to 10^{18} eV at a altitude of around 100 gcm^{-2} above Mt. Chacaltaya. We have dtermined lateral distributions of the electromagnetic component (for simplicity, we call this component as gamma ray) with energy above 2 TeV and also the hadronic component of energy above 6 TeV of this air shower core respectively. These lateral distributions may also ones at the very early stage of air shower development.

We have also studied so-called $E_\gamma R_\gamma$, $E_H^\gamma R_H$ distribution. Here E_γ, E_H^γ are the energy of each gamma ray and hadronic γ ray respectively. R_γ, R_H are the radial distance from the center of the bundle of these particles. As well known, we can determine the transverse momentum from the product of energy and distance of a particle (ER) divided with a production height (H).

Since particles in the bundle are produced with process of the development of the nuclear cascade, we can not know the primary energy of each interaction in the cascade which produces these particles. In order to know the primary energy dependence of transverse momentum, we study the average products of energy and distance ($\langle ER \rangle$) for various average energies of secondary particle ($\langle E \rangle$).

2. Lateral distribution of gamma rays and hadrons

Centers of the bundle are determined from the energy weighted mean of positions of gamma rays and hadrons respectively. The deviation between two centers is only less than 1 mm and both are in agreement.

Lateral distributions of gamma rays and hadrons are shown in Fig.1 and Fig.2 for two different threshold energies. The slopes of these distributions are in agreement.

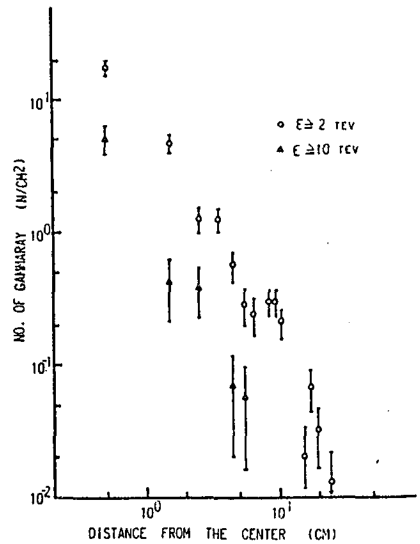

Fig.1. Lateral distribution of gammarays.

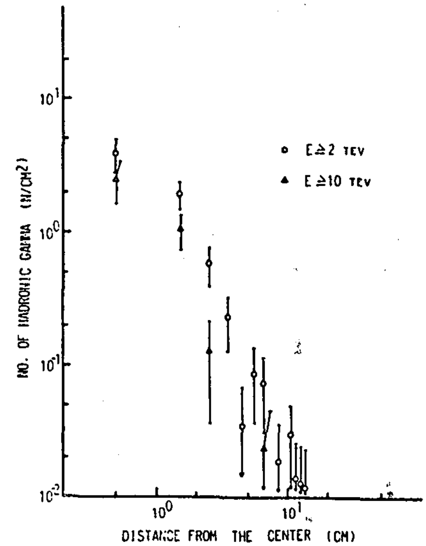

Fig.2. Lateral distribution of hadrons.

Distributions are represented by the power law of the form r^{-n}. The exponent (n) is about 1.8 for gamma rays and about 1.9 for hadrons.

3. ER distributions

ER is the parameter which reflect the transverse momentum of that particle. Fig.3 and Fig.4 show ER distribution for gamma rays and hadrons respectively. The distributions for hadrons with energy more than 10 TeV is flatter than others untill higher ER values.

The relation between the averages, $\langle ER \rangle$ and $\langle E \rangle$, are

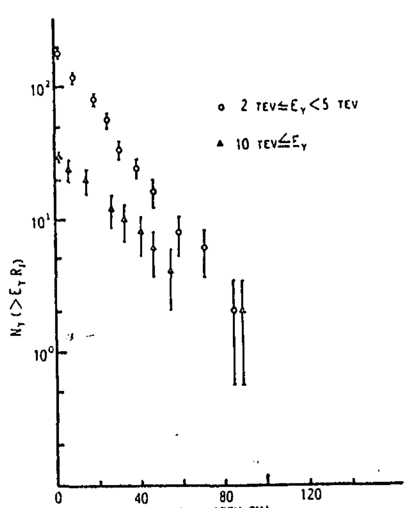

Fig.3. ER distribution of gammarays.

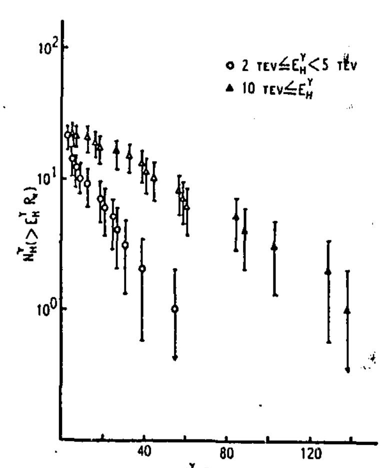

Fig.4. ER distribution of hadrons.

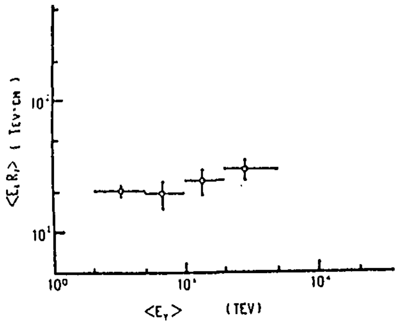

Fig.5. Relation between the average of ER and E of gammarays.

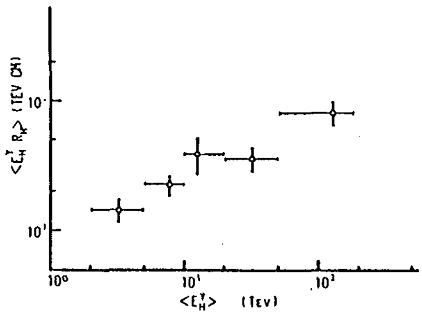

Fig.6. Relation between the average of ER and E of hadrons.

shown in Fig.5 and Fig.6 for gamma rays and hadrons. The average $\langle ER \rangle$ increase with increasing the mean energy $\langle E \rangle$. This tendency is remarkable for high energy hadrons. This tendency is found in ER distributions of gamma rays and hadronic gamma rays of events Andromeda and M.A.Ⅲ. These events are the most high energy events among five families of the highest energy range, $\Sigma E_\gamma > 1000$ TeV observed by Chacaltaya Emulsion Chamber Experiment of Brasil-Japan Collaboration.[1]

4. Energy dependence of transverse momentum

Transverse momentum is determined from ER divided by production height. In the air shower, hadrons are not produced in a single interaction, but individual interactions at different stages in a nuclear cascade of air shower development. Radial distance R, however, corresponds to radial deviation caused by final interaction in which that particle is produced. Therefore, we can estimate P_T with these R and an estimated most probable production height above the observation level. In the present case, we use 80 gcm^{-2} which is consistent to a height estimated from calculations of air shower development. We estimated P_T with $P_T=(E_H^\gamma \times 3 \times R)/H$ for hadron and $P_T=(E_\gamma \times 2 \times R)/H$ for gamma ray. Facter 3 comes from the charge symmetry in hadron interaction and facter 2 from two gamma decay of a neutral pion. Result are shown in Fig.7. In the figure, we show also data obtained from CERN experiments.[2] In order to compare the accelerator results with present results, interaction energy in the laboratory system transfered from colliding particle energy is divided with the average multiplicity of secondary particles.[3] Two points obtained from ISR and P$\bar{\text{P}}$ collider are connected with a dashed line. The present results are on the extrapolation of this line. In spite of uncertainty of air shower experiments, these data seem to be in good agreement. In the higher energy region, P_T increase much largely apart from the extrapolation of the energy dependence of lower energy region.

This figure shows that P_T increase with the power law of the average energy of shower particle of the form E^n of the

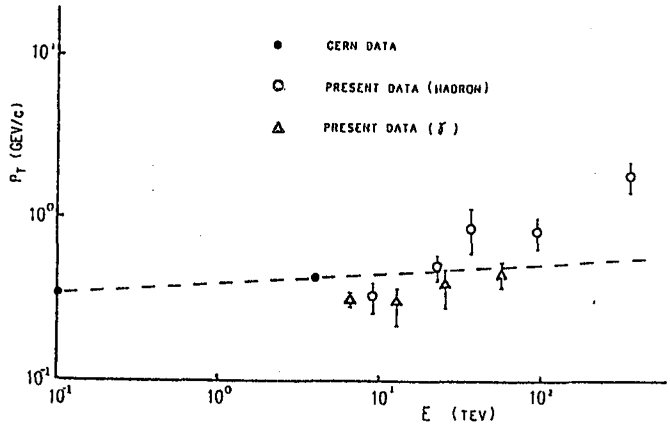

Fig.7. Relation between $\langle P_t \rangle$ and shower particle $\langle E \rangle$.

exponent n=0.06. However, in the extremely high energy region, the exponent increase to n=0.44.

In model calculations on the nuclear cascade of energy around 10^{17} eV, high energy hadrons can not be produced by secondary pion after passing through 80 gcm^{-2}. Consequently, hadrons with energy more than 100 TeV may be produced in fragmentation region of nucleon interaction.

We can conclude that this remarkable increase of P_T for hadrons above 100 TeV with increasing average hadron energy may be a noteworthy characteristics of the energy dependence of transverse momentum especially in the fragmentation region.

Acknowlegements

This work was supported by the Grant-in-Aid for Oversea Survey of the Ministry of Education, Science and Culture in Japan. The authors wish to thank prof. C. Grupen, Siegen University, for fruitful discussion during his stay in Japan.

References

1) Yamashita,S., et al, ICR-Report-112-83-6, 123(1983)
2) Arnison,G., et al, UA1 Collaboration,
Proc. Third Topical Workshop, CERN 83-04,75(1983)
3) Ward,D., et al, UA5 Collaboration,
Proc. Third Topical Workshop. CERN 83-04,75(1983)